BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 12086

SUBJECT: MSFC POGO Working Group Meeting - Case 320

DATE: December 23, 1969

FROM: A. T. Ackerman
J. J. O'Connor
R. V. Sperry

ABSTRACT

A POGO Working Group meeting was held at MSFC on December 16. Several contractors, including Bellcomm, and MSFC laboratories presented results of their analyses to evaluate the use of a center LOX line accumulator to suppress POGO on the S-II. The attached charts were presented by Bellcomm. There was a general recommendation that an accumulator be installed on S-II-8 (for Apollo 13) but that there was no mandatory requirement for it.

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MEMORANDUM FOR FILE

The authors attended the POGO Working Group Meeting at MSFC on December 16. The purpose at the meeting was to determine if the several periods of POGO experienced on S-II-7 (Apollo 12) require the installation of an accumulator on the S-II center engine LOX line for Apollo 13. The attached vu-graphs presented at that meeting fulfilled specific requests made by MSFC for us to analyze their LOX line test rig data and to examine the stability sensitivity of certain accumulator parameters.

The first chart lists several features of our test rig analysis. (More details of our model had been given at a previous meeting.*) The second chart shows a sample of the analysis-test comparison which supports the conclusions listed on the third chart, viz: the first resonance of the line/accumulator in a flight configuration is about 1 Hz lower than that measured in the test rig (3.5 vs 4.5 Hz); the analysis indicates a zero or anti-resonance at 9 Hz which is obscured in the test data; and the slope of the data between 9 and 28 Hz should not lead to the posulation of a second resonance at 30 Hz but is adequately explained by the 50 Hz second resonance of the analysis. The amplitude of the resonance peaks indicates that the damping in our model is far less than the physical test setup.

The fourth chart lists the features of our S-II stability analysis, while the structural frequencies and gains are shown in the next two charts. The seventh chart shows our evaluation of an accumulator, with the no-accumulator-case shown for reference. This no-accumulator-case gives a fair reproduction of the 504 experience (Apollo 9). There is a 16 Hz mode (n=6) with marginal stability (2 dB) during most of the flight. (Since our model does not yet contain several higher tank modes, it does not reproduce the several stability-instability periods during this time period as observed on 507.) Late in flight, the minimum stability mode shifts to a lower mode (n=5), still in the 15-17 Hz region; the last point (17.2 Hz) is a still

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*"Presentation Made to the S-II POGO Working Group Meeting," Case 320, A. T. Ackerman, October 20, 1969.

lower mode (n=4). The 2 dB instability in the 340 to 360 second time period is close to the 504 flight experience.

The dashed curves on the seventh chart show that the accumulator adds about 12 dB of stability to the 15-17 Hz modes. There is also a mode associated with the first resonance of the LOX line with accumulator (4 Hz) but it is at least 24 dB stable. The investigation of a lower frequency second resonance (35 vs 50 Hz) showed a minimum stability of 4 dB which is between the no-accumulator and the nominal accumulator cases. However, as shown above, we don't believe the second resonance is lower than 50 Hz.

The eighth chart summarizes the conclusions we draw from our analysis. The ninth chart, recommendations, really gets down to the nitty-gritty. It says we recommend that the program plan to install an accumulator on Apollo 13 but, due to reservations we have about the lack of perfect reproduction of the 504 experience, the failure to predict the 507 events and the possible transient effects while the accumulator is being charged after engine ignition, a backout option be maintained as late as possible within the launch schedule.

The several contractors* and MSFC laboratories presented various degrees of their analyses, but each made a recommendation. An ensuing discussion pointed out the difference between a recommendation and a mandatory requirement. Without too much blurring of individualities, it is safe to say there was unanimous consent that an accumulator is recommended and/or highly desirable; no one held out that it is mandatory. While this may be quibbling about words, we think our opinion may be typical: all indications now show an improvement with an accumulator; an adverse affect would have to be shown to recommend against its incorporation; and the launching of Apollo 13 without an accumulator (due to cost and/or schedule impact) might be justified on the basis of previous flights.

*See Agenda.

A. T. Ackerman

J. J. O'Connor

R. V. Sperry

2031-JJO-jct

Attachments

SUCTION LINE - ACCUMULATOR TEST RIG ANALYSIS

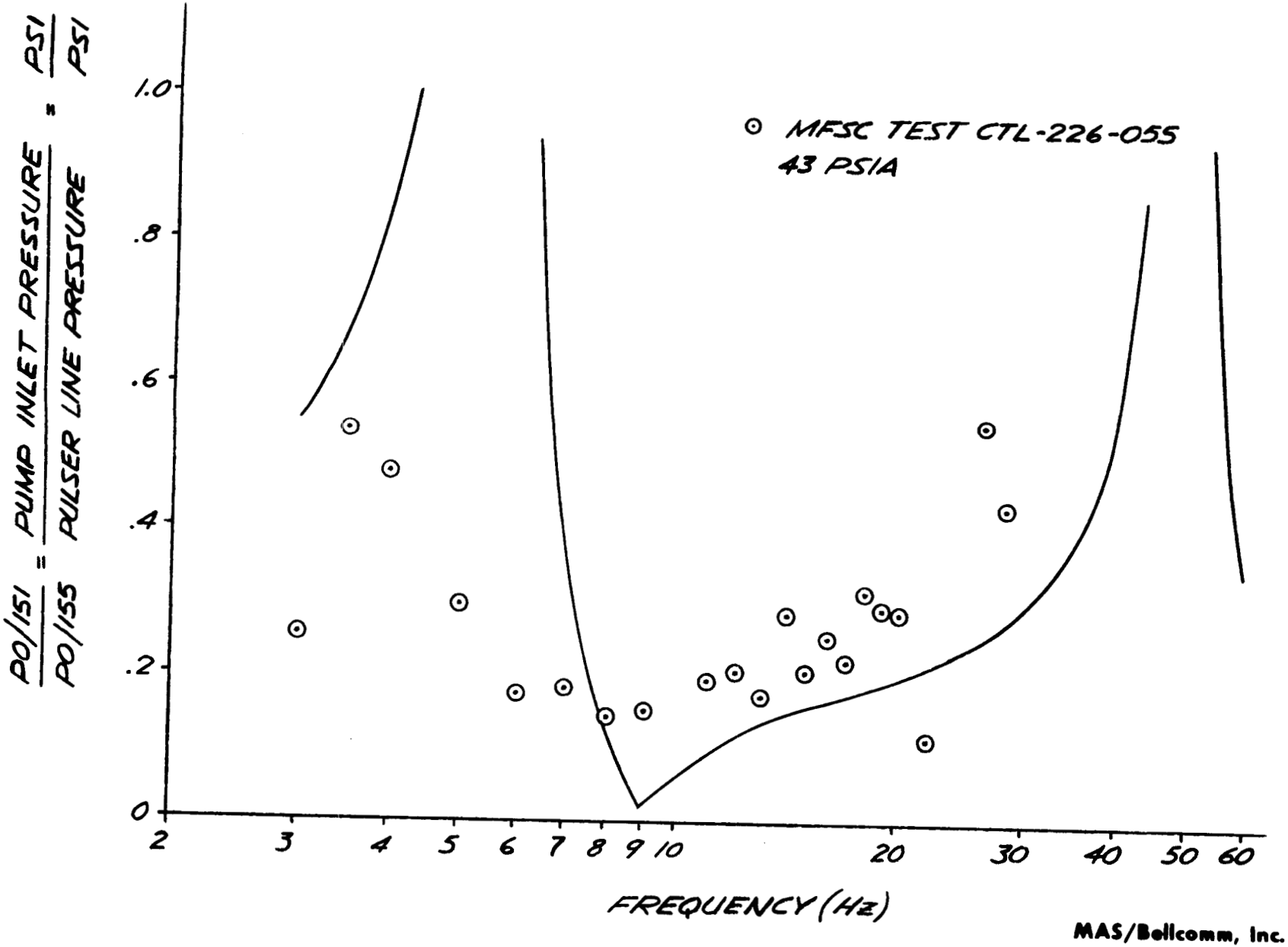
A MATH MODEL WAS USED TO ANALYZE THE MSFC SUCTION LINE/ACCUMULATOR TEST RIG. THE GOAL WAS TO DETERMINE THE FIRST AND SECOND RESONANCES OF THE SUCTION LINE WITH THE ACCUMULATOR AND PUMP TERMINATION.

WE ASSUMED PULSER FLOW AND CALCULATED THE PULSER PRESSURE AND THE SUCTION LINE PRESSURE.

THE RESULTS COMPARED FAVORABLY WITH THE TEST RESULTS WITHIN THE LIMITATIONS OF DETERMINING:

1. TOTAL DAMPING OF THE SYSTEM.
2. THE NOISE LEVEL OF THE SUCTION LINE TRANSDUCER.

COMPARISON OF BELLCOMM MATH MODEL WITH MSFC S-II INBOARD LOX LINE TEST DATA



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CONCLUSIONS (TEST RIG)

- THE FIRST RESONANCE OF THE LINE, ACCUMULATOR, AND PUMP OCCURS AT APPROXIMATELY 1 HZ LESS THAN THE PEAK OF THE RATIO OF SUCTION PRESSURE TO PULSER PRESSURE. ($\sim$3.5 HZ INSTEAD OF 4.5 HZ.)

- THE FIRST ZERO OF THE LINE WITH THE ACCUMULATOR OCCURS AT APPROXIMATELY 9 HZ.

- THE SECOND RESONANCE OCCURS AT APPROXIMATELY 50 HZ.

- THE RISING CHARACTERISTIC OF THE RATIO OF SUCTION PRESSURE TO PULSER PRESSURE BETWEEN 9 HZ AND 28 HZ IS DUE TO THE 50 HZ SECOND RESONANCE - NOT DUE TO A 30 HZ SECOND RESONANCE.

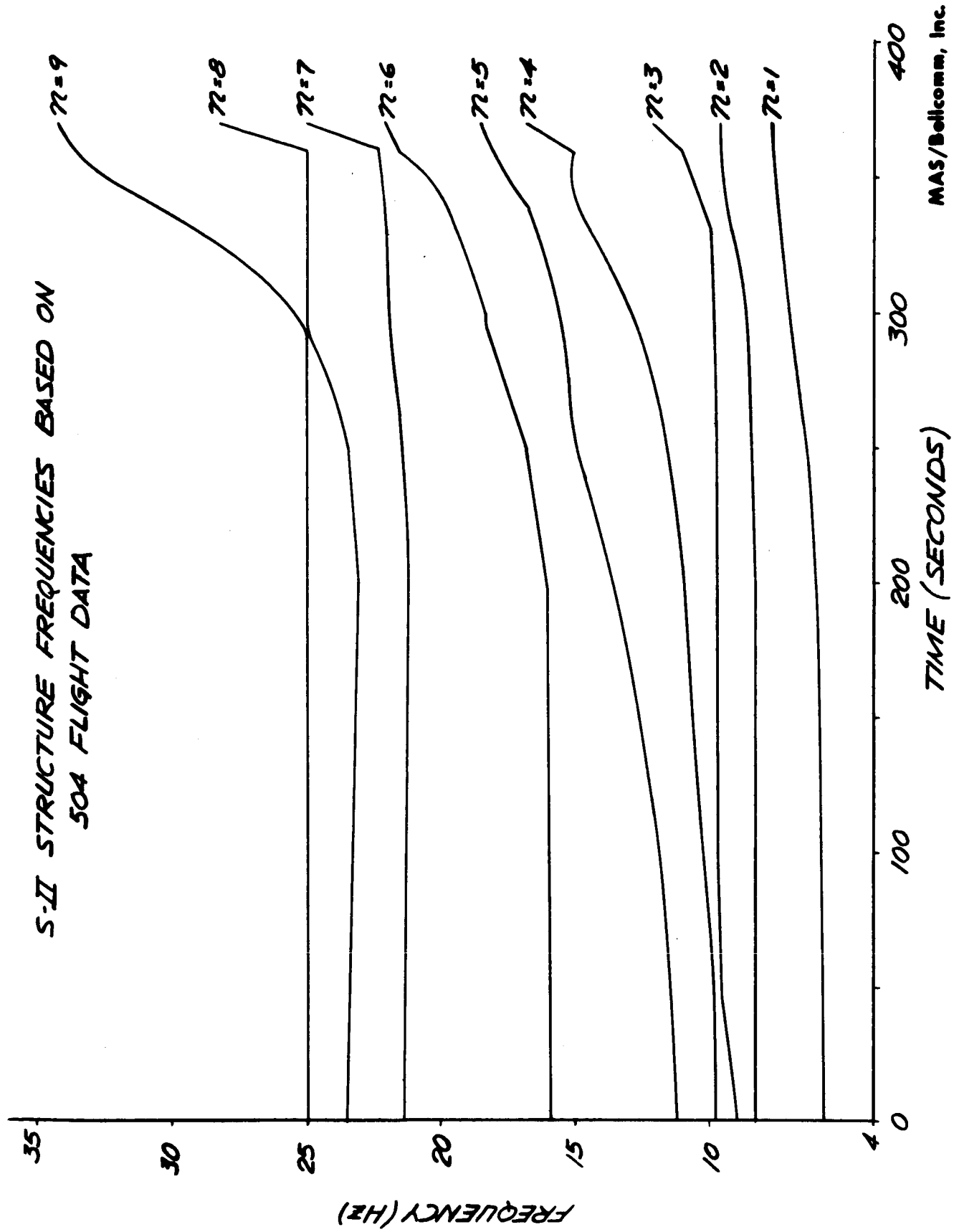
S-II STABILITY ANALYSIS

- STRUCTURAL MODEL GENERATED BY BELLCOMM WITH A TWO MODE REPRESENTATION OF THE LOX TANK. (MATCHES 504 FLIGHT DATA.)

- DAMPING A FUNCTION OF RELATIVE CENTER ENGINE - TANK BOTTOM DISPLACEMENT. (MAX VALUE ◻ 4.5%.)

- ROCKETDYNE ENGINE TRANSFER FUNCTIONS.

- 26 HZ LOX SUCTION LINE.


S-II STRUCTURE FREQUENCIES BASED ON
SO4 FLIGHT DATA
n=9
n=8
n=7
n=6
n=5
n=4
n=3
n=2
n=1
35
30
25
20
15
10
4
0
100
200
300
400
FREQUENCY (HZ)
TIME (SECONDS)
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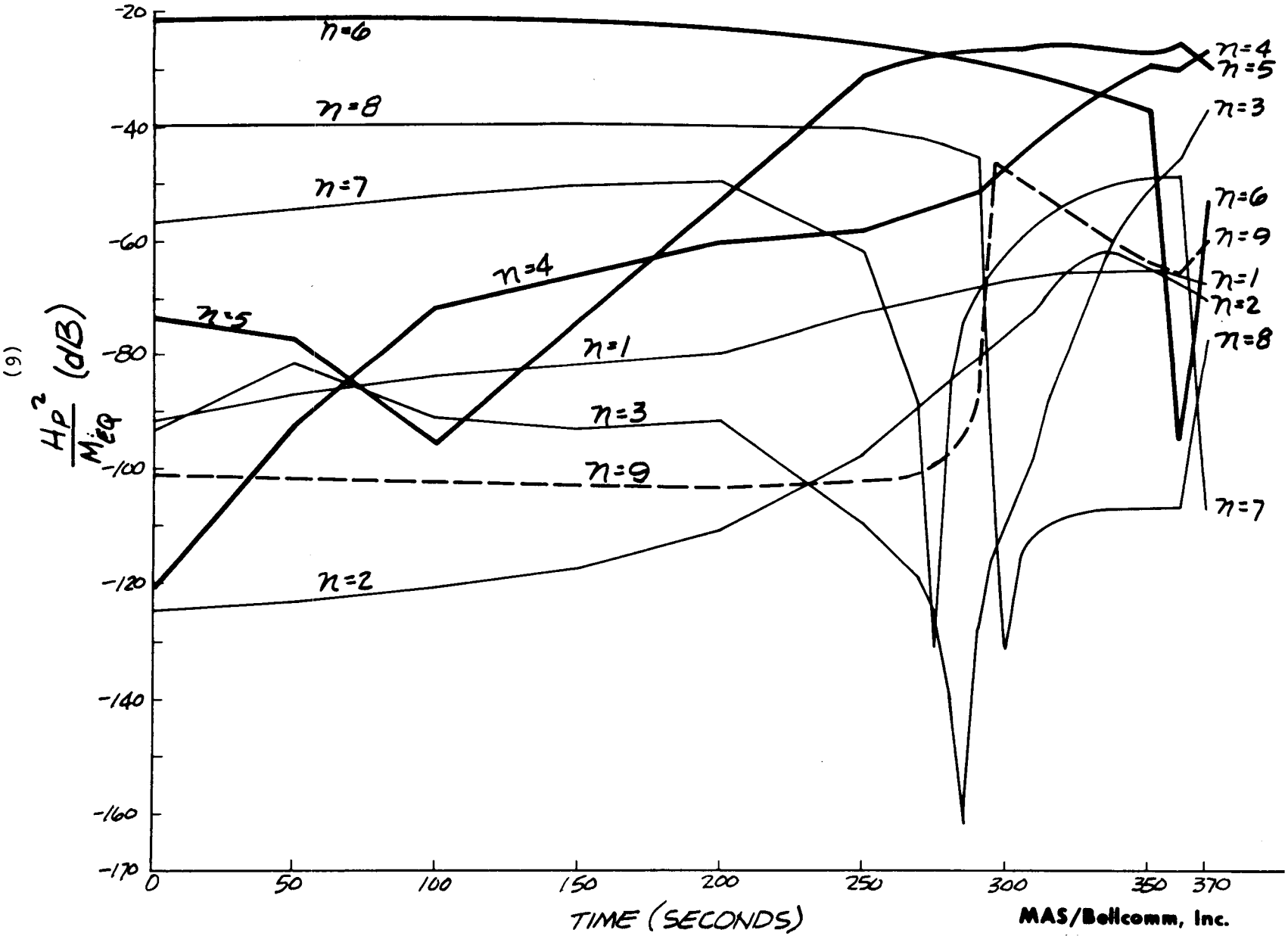
S-II STRUCTURE GAINS BASED ON SA-504 FLIGHT DATA



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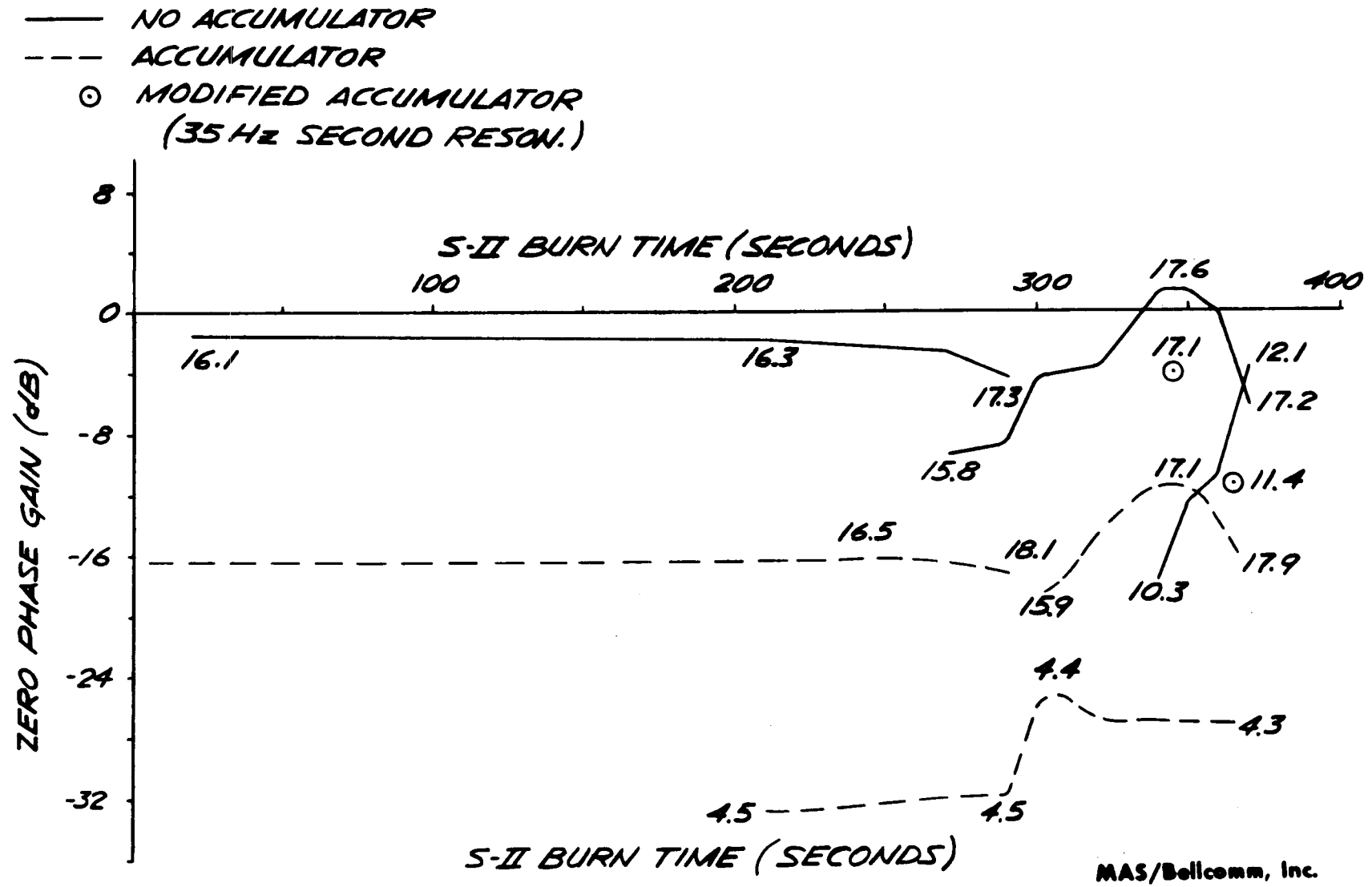
S-II INBOARD STABILITY (OUTBOARD LOOP OPEN)
BELLCOMM S-II STRUCTURE
MSFC LOX LINE
ROCKET DYNE ENGINE



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CONCLUSIONS (STABILITY)

WITHIN THE LIMITATIONS OF OUR MODEL WE CONCLUDE

- THE ACCUMULATOR IMPROVES THE STABILITY IN THE 17 HZ REGION FOR ALL TIMES OF FLIGHT.

- WITH THE ACCUMULATOR THE SYSTEM MAINTAINS LARGE STABILITY MARGINS AT ALL FREQUENCIES THROUGHOUT FLIGHT.

- ACCUMULATOR FAILURE IS POTENTIALLY MORE HAZARDOUS THAN FOR THE SIC CASE.

RECOMMENDATIONS

- PLAN TO FLY APOLLO 13 WITH THE ACCUMULATOR.

- MAINTAIN THE ABILITY TO FLY WITHOUT AN ACCUMULATOR IF SUBSEQUENT ANALYSIS INDICATES A PROBLEM.

- CONTINUE STABILITY ANALYSIS TO EVALUATE IMPROVED STRUCTURAL MODELS AND THE CONSEQUENCES OF THE ACCUMULATOR FILL SEQUENCE AND ACCUMULATOR FAILURE MODES.

- PLAN TO ELIMINATE EARLY CECO ON APOLLO 14 AND SUBS IF ANALYSIS CONTINUES TO INDICATE LARGE STABILITY MARGINS WITH THE ACCUMULATOR.

AGENDA
POGO WORKING GROUP MEETING
December 16, 1969

1.	INTRODUCTION	J. Sterett	8:30 - 8:40
2.	S-II POGO ASSESSMENT		
	a. NR/SD	W. Ezell	8:40 - 9:40
	b. NR/RKD	J. Fenwick	9:40 - 10:00
	c. MSFC/ASTN	T. Bullock	10:00 - 10:20
	d. MSFC/AERO	L. Kiefling	10:20 - 10:35
	e. MSFC/ASTR	E. George	10:35 - 10:40
	f. BELLCOMM	R. Sperry	10:40 - 11:00
	g. TBC/HSV	L. McTigue	11:00 - 11:15
	h. MMC	R. Vaage	11:15 - 11:30
3.	DISCUSSION OF RECOMMENDATIONS	J. Sterett	11:30 - 11:50
4.	SUMMARY AND CONCLUDING REMARKS	J. Sterett	11:50 - 12:00